# Science Focus Work Group Products

## Atmospheric Composition

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# Atmospheric Composition

# Critical Science Questions

**Existing Roadmaps:** *Given what we have heard about UAV potential, what of the 2007-2015 Roadmap goals could be addressed from a SUBORBITAL platform?*

- Assessment of the potential for future major depletion of Arctic $O_3$
- Strat. $O_3$ recovery in changing climate; assessment of trop. $O_3$ trends & mechanisms
- Validation of changes in trop. and strat. $O_3$, water vapor, aerosols and potential impacts of future changes on climate & atmospheric chemistry
- Evaluations of feedbacks between aerosols, $O_3$, $H_2O$, & climate
- Evaluation of chemistry/climate interactions with multi-decadal simulations of the strat & trop. Quantify mechanisms for evolution of trop $O_3$.
- Operational predictions linking $O_3$ & aerosols with climate & air quality

**Other Roadmap Possibilities:** *Are there other things that should be in the Roadmap now that we see what is possible?*

- Linkage to climate & cloud physics (climate roadmap), hydrological cycle (water and energy cycle), weather (weather roadmap), carbon cycle (carbon cycle roadmap)

**Phasing Observations:** *How would we phase the critical observations in our Earth Science focus area that are most suitable for the suborbital platform realm?*

<u>High resolution (vertical, horizontal, and temporal), simultaneous observations measured over long range are necessary to elucidate physical and chemical processes. These fine scale observations are extendable to the global scale satellite observations.</u>

- Strat ozone chemistry: profiling of source gases, water, aerosols, and temperature in the mid-latitudes and polar regions in the UT/LS.
- Trop pollutants: profiling of pollutants and particles and their source emissions on regional to hemispheric scales from near the surface to the tropopause region.
- Water vapor and total water: profiling of water from the mid-troposphere to the lower stratosphere from the tropics into the mid-latitudes.
- Clouds & aerosols: profiling of cloud and clear sky environments (optical, composition, and microphysical parameters) to examine chemical variability of aerosols and direct and indirect chemical and radiative effects of clouds and aerosols.

# Atmospheric Composition – Cloud & Aerosol

**<u>Critical Observation</u>: Study transformations of aerosols and gases in cloud systems for:**

- Convective systems – 100's of km (Costa Rica, So. Florida, Central US)
- Sea breeze cloud formation -100's of km (US coastal)
- Marine stratiform – 100's of km (California coastal)
- Contrails (Central US in air traffic regions) & ship tracks (ocean) – 100's of km
- Synoptic scale systems & Fronts – 1000's of km (Central US)
- Cirrus outflow – 1000's of km (tropics, So. Florida, Central US)

- Profiling of cloud and clear sky environments (optical, composition, and microphysical parameters) to examine variability of aerosols and direct and indirect chemical and radiative effects of clouds and aerosols.

- Investigate fundamental microphysics of cloud drop formation and evolution by looking at inflow/outflow through these systems to see the transformations. For example, we would look at inflow into cumulus convection in the boundary layer and lower troposphere and the outflow in the mid-to-upper troposphere. Aerosols and pollutants are modified by these convective systems as they are lofted into UT/LS. These flights may occur in severe convective environments (i.e., strong vertical wind shear, severe lightning).

- Formation flying (4 aircraft): 3 in-situ sampling aircraft to sample in-flow region, out-flow region, and convective core, and a high altitude remote sensing aircraft (near tropopause).

- Pre-programmed flight scenario with re-tasking during the mission. Over the horizon communication control of aircraft by ground base. Near real-time re-tasking based upon observations from remote sensing platform. Observations of these aerosol & cloud events synergistic with satellite platforms.

# Atmospheric Composition – Cloud & Aerosol

**<u>Observation / Measurement Definition</u>: Describe the phenomenon you want to observe. Describe what you need to measure.**

<u>Measurements (simultaneous):</u>
- Water vapor, total water
- Temperature, Pressure, Winds
- Ozone
- Lightning
- Aerosols & cloud particles
  - Chemical composition
  - Number, size, volume
  - Habit
  - Extinction & absorption
- Source gases & tracers
  - Hydrocarbons
  - Formaldehyde
  - $HNO_3$
  - $NO_y$
  - $CO_2$, CO
  - HCl
  - $CH_3I$
  - Sulfur species (e.g., $H_2SO_4$, $SO_2$)
- Radicals
  - NO, $NO_2$
  - OH, $HO_2$
  - $RO_2$

**Explicitly state how this observation and measurement supports this Earth Science focus area.**

- Primary question in the ESE strategic plan.

**Explicitly state the advantage of using a suborbital platform for this measurement.**

- High spatial and temporal resolution, overlap with and extension of satellite observations. The measurements aboard a suborbital system can be chosen to be much more comprehensive than the planned and operational satellite instruments. Improved targeting of atmospheric phenomena (e.g., Lagrangian sampling). Instruments can be calibrated in the air and on the ground pre and post-flight. Measurement flexibility and greater capability for instrument upgrades.

**Identify other cross-cutting areas impacted by this observation.**

- Climate change, hydrological cycle, weather

# Atmospheric Composition – Cloud & Aerosol

**<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:**

**Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)**

- All instruments have own computers and data storage. Aircraft performance (altitude, latitude, longitude, time, attitude) required.

<u>Measurements (remote):</u>
Water vapor (lidar1)
Temperature (lidar2, uwave3, dropsonde4), Pressure, Winds (9.5 Doppler radar5)
Ozone (lidar2, FTIR6, UV-Vis7)
Lightning (optical8)
Aerosols & cloud particles (ice water content) (lidar2, radar9: 95 Ghz)

<u>Remote Sensing platform:</u>
9 instruments
total weight = 2000 lbs. (current individual instruments range from 50-500 lbs.)
total volume = 150 cu. ft.
environmental conditions – nadir windows for lidar (16 in. diameter), UV-Vis requires a relatively uninhibited horizon view, side window ports for microwave and FTIR, nadir windows for radars.
total power = 10 kW

<u>Measurements (in-situ inflow and outflow regions; * convective core - UAHumV):</u>
Water vapor(1)*, total water(2)*, isotopic water
Temperature*, Pressure*, Winds* (3)
Ozone (4)
Lightning* (5)
Aerosols* & cloud particles* (6-11)
Chemical composition
Number, size, volume
Habit
Extinction & absorption
Source gases & tracers (12-21)
Hydrocarbons (2)
Formaldehyde (1)
$HNO_3$(1)
$NO_y$*
$CO_2$*, CO*
HCl
$CH_3I$*

# Atmospheric Composition – Cloud & Aerosol

- Sulfur species (e.g., $H_2SO_4$, $SO_2$)

Radicals (22-24)

- $NO$, $NO_2$
- $OH$, $HO_2$
- $RO_2$

<u>In-situ inflow/outflow platforms (simultaneous, high frequency observations)</u>

24 instruments

- total weight = 2800 lbs. (current individual instruments range from 35-400 lbs.)
- total volume = 180 cu. ft.
- environmental conditions – free stream sampling, no pressurization, some air flow scoops and venting, instrument cooling is a major issue for tropospheric sampling – active temperature control may be necessary.
- total power = 10 kW

<u>In-situ convective core (UAHumV) platform (simultaneous, high frequency observations)</u>

14 instruments

- total weight = 1600 lbs. (current individual instruments range from 35-400 lbs.)
- total volume = 100 cu. ft.
- environmental conditions – free stream sampling, no pressurization, some air flow scoops and venting, instrument cooling is a major issue for tropospheric sampling – active temperature control may be necessary.
- total power = 8 kW

## Atmospheric Composition – Cloud & Aerosol

**Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.**

- Locations:
  Convective systems – tropics, So. Florida, Central US
  Sea breeze cloud formation -US coastal
  Marine stratiform – California coastal
  Contrails (Central US in air traffic regions) & ship tracks (ocean)
  Synoptic scale systems & Fronts –Central US
  Cirrus outflow –tropics, So. Florida, Central US

- Altitude:
  Remote: FL 400-600
  In-situ in-flow: near surface to FL200
  In-situ out-flow: FL 200-600
  In-situ UAHumV: FL 200-500
- Range: 6000 km
- 0.4 < Mach number < 0.7
- Endurance: 24 hours
- Season: winter, spring, summer, fall
- Frequency: daily flight capability with up to 3 flights per week. 4 week campaigns
- g-loading: mountain wave and convection induced turbulence common. UAHumV aircraft must essentially be an "armored" UAV capable of sustaining severe turbulence (50 m/s downdrafts), lightning strikes, and large hail.
- Cross wind takeoff capability of 25 kts, 35 kts total.

**Communication needs such as real-time data or instrument control**

- Real time communication for re-tasking aircraft in mid-air as meteorological, cloud, and near real time radar imagery evolves. Over the horizon capability is essential. Minimum 9600 baud for instruments.

# Atmospheric Composition – Cloud & Aerosol

**<u>Mission Concept</u>: Describe in as much detail as possible the measurement approach:**

**Provide a narrative describing a “cycle-in-the-life” of the mission.**

1) Instrument preparation
2) Initial mission planning
3) Mission programming or pilot briefing
4) Instrument upload
5) Takeoff
6) Time-to-target
7) Real-time data transmission & radar imagery leading to aircraft formation re-tasking
8) Return to base
9) Instrument download
10) Instrument & aircraft servicing
11) Data analysis
12) Mission objective revisions based upon flight results

**Develop a diagram showing flight profile or maneuvers in time, space and/or geographic coordinates.**

1) Takeoff from base.
2) Remote platform ascends to maximum altitude
3) All aircraft proceed towards predicted cloud systems
4) In-situ platforms adjust altitudes to: inflow region (near surface < 10 kft. for in-flow platform), outflow (mid-troposphere 10-55 kft for outflow platform), convective core (25-55 kft for convective core, UAHumV platform), and near tropopause (remote sensing platform).
5) In-situ aircraft are vectored on multiple passes across or through the cloud system (as determined by remote platform observations and radar). Altitudes are adjusted amongst in-situ to capture cloud features.
6) Descent to base.

**Identify any special or unique platform or mission issues**

- Capability to release a tracer chemical in the boundary layer near the bottom of the in-flow region and trace its transport through the cloud system to the out-flow region.

- Ground-based radar system for identifying possible cloud system targets and for directing aircraft to such systems.

- Terrain following radar necessary for boundary layer in-situ platform.

## Atmospheric Composition – Cloud & Aerosol

**Summarize the key elements of the mission concept for this measurement.**

- A mission to study the sources, evolution, distribution and impact of tropospheric aerosols and clouds. The main elements of this mission are:

  1) Moderate range (6,000 km),
  2) 24-hour duration,
  3) Multiple coordinated platforms with real time command capability,
  4) Heavy lift (24 instruments - 2800 lbs.),
  5) High duty cycle (3 flights per week over a month long campaign), and
  6) An armored UAV for flying in severe storms.

# Atmospheric Composition – Stratospheric 0zone

**Critical Observation: Stratospheric ozone chemistry:** profiling of source gases, water, aerosols, and temperature in the mid-latitudes and polar regions in the UT/LS.

**Observation / Measurement Definition: Describe the phenomenon you want to observe. Describe what you need to measure.**

- Recovery of the stratospheric ozone layer. Will the ozone layer (i.e., Antarctic ozone hole, Arctic ozone levels, mid-latitude) recover to pre-1980 levels? How will climate change interact with the expected decrease of ODS?

- Measurements (simultaneous):
    - Water vapor, total water
    - Temperature, Pressure, Winds
    - Ozone
    - Aerosols & Polar stratospheric clouds
    - Source gases & tracers
        - Halocarbons
        - $N_2O$, $CH_4$, $SF_6$, $CO_2$, CO
        - COS, Isotopes
    - Reservoir species
        - $HNO_3$
        - HCl
        - $ClONO_2$
    - Radicals
        - ClOx
        - BrO
        - NOx
        - HOx
        - IO
    - UV-Vis

**Explicitly state how this observation and measurement supports this Earth Science focus area.**

- Primary question in the ESE strategic plan.

# Atmospheric Composition – Stratospheric 0zone

**Explicitly state the advantage of using a suborbital platform for this measurement.**

- High spatial and temporal resolution, overlap with and extension of satellite observations.
- The measurements aboard a suborbital system can be chosen to be much more comprehensive than the planned and operational satellite instruments.
- Improved targeting of atmospheric phenomena (e.g., Lagrangian sampling).
- Instruments can be calibrated in the air and on the ground pre and post-flight.
- Measurement flexibility and greater capability for instrument upgrades.

**Identify other cross-cutting areas impacted by this observation.**

- Climate change.

**Observation / Measurement System Requirements: Describe how you want to observe or measure the phenomena. Consider the following:**

**Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports):**

- All instruments have own computers and data storage.
- Aircraft performance data (altitude, latitude, longitude, time, attitude) required by the instruments.
- Experimenters need easy access to instruments, and instruments will probably be off-loaded from aircraft after each flight.
- All instruments weight, volume, and power estimates are based upon current capabilities.

21 In-situ instruments
total weight = 2500 lbs. (current individual instruments range from 35-400 lbs.)
total volume = 150 cu. ft.
environmental conditions – **free stream sampling**, no pressurization, some air flow scoops and venting
total power = 10 kW

6 Remote sensing instruments: 2 lidars, 1 FTIR, 2 microwave, 1 UV-Vis
total weight = 1000 lbs. (current individual instruments range from 35-500 lbs.)
total volume = 75 cu. ft.
environmental conditions – both zenith and nadir windows for lidar (16 in. diameter), UV-Vis requires a relatively uninhibited horizon view, side window ports for microwave and FTIR.
total power = 10 kW

# Atmospheric Composition – Stratospheric 0zone

**Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics:**

- Location: basing flexibility to provide access from mid-latitudes to either pole
- Altitude: **FL 300-700**
- Range**: 24,000 km**
- Speed: 0.4 < Mach number < 0.7
- Endurance: **2-5 days**
- Season: winter (polar night, extremely cold in Antarctic vortex in mid-winter, 180 K), spring, summer, fall
- Frequency**: 48-hour turnaround. ~1 flight every week during a campaign.** Campaigns will last approximately 1 month (2-3 flights/campaign). A Northern experiment with campaigns in Dec., Jan., Feb., and Mar. of a particular winter. A Southern experiment with campaigns in Jul., Aug., Sep., Oct. (not necessarily the same year as the Northern campaign).
- Reliability: The mission requires 1000 flight hours over a 4-month period without major interruptions.
- Basing: mid-to-low latitudes in the Northern hemisphere for the Northern campaign and in the Southern hemisphere for the Southern campaign.
- g-loading: mountain wave induced turbulence common in polar regions, aircraft must be able to sustain nominal turbulence comparable to ER-2 (3 g's).
- Takeoff capability: cross wind max of 20 kts, 30 kts total.

**Communication needs such as real-time data or instrument control**

- Real time communication for re-tasking aircraft in mid-air as meteorological, PSC, and chemical forecasts evolve. **Over the horizon capability is essential.** Minimum 9600 baud for instruments.

# Atmospheric Composition – Stratospheric 0zone

**Mission Concept: Describe in as much detail as possible the measurement approach:**

**Provide a narrative describing a “cycle-in-the-life” of the mission.**

1. Instrument preparation
2. Initial mission planning
3. Mission programming or pilot briefing
4. Instrument upload
5. Takeoff
6. Time-to-target
7. Real-time data transmission & updated forecasts leading to plane re-tasking
8. Return to base
9. Instrument download
10. Instrument & aircraft servicing
11. Data analysis
12. Mission objective revisions based upon flight results

**Develop a diagram showing flight profile or maneuvers in time, space and/or geographic coordinates.**

1. Takeoff from base (e.g., Dryden).
2. Ascend to cruise altitude at 2500 ft./min.
3. Proceed northward towards polar vortex
4. Vertical profiles from maximum altitude to below tropopause every 10˚ of latitude ~ 2000 ft./minute. Spiral descents.
5. Cross the polar vortex boundary
6. Aircraft targeted on PSC in high Arctic
7. Lagrangian sampling downstream of PSC
8. Race-track sampling of PSCs over Scandinavian mountains (some turbulence expected). Temperatures are approximately 190 K. Wind speeds of 100 kts.
9. Re-cross polar vortex on return, spiral descent vertical profiles every 10˚ of latitude ~ 2000 ft./minute.
10. Descent to base

**Identify any special or unique platform or mission issues**

- Crenellation flights – aircraft flies at two alternate levels (e.g., FL650 and FL450) switching altitudes every 20-30 minutes. May choose upper altitude to be maximum altitude.

- Isentropic flight – aircraft adjusts altitude in order to remain on a fixed isentrope [□ =T ( P/1000 )$^{3.5}$].

# Atmospheric Composition – Stratospheric 0zone

**Summarize the key elements of the mission concept for this measurement.**

- A mission to study stratospheric ozone recovery as ozone depleting substances decrease and the effects of climate change on this recovery from the mid-latitudes to the pole. The main elements of this mission are: 1) long range (24,000 km), 2) long duration (2-5 days), 3) high altitude (70,000 feet), 4) heavy lift (27 instruments - 3500 lbs.), and 5) high reliability.

- An alternative scenario for this mission might be to split the payload into in-situ and remote sensing instruments and to fly these payloads in formation on two separate aircraft.

# Atmospheric Composition – Tropospheric 0zone

**Critical Observation: Tropospheric pollution and air quality:** profiling of pollutants and particles and their source emissions on regional to hemispheric scales from near the surface to the tropopause region. Determine where plumes of pollution are transported and how they evolve.

- Formation flying (4 aircraft): Boundary in-situ, mid-trop in-situ, upper-trop in-situ, high altitude remote sensing (near tropopause).
- Pre-programmed scenario with re-tasking during the mission. Over the horizon communication control of aircraft by ground base. Near real-time re-tasking based upon observations from remote sensing platform. Following plume events over several days and over 10,000 km. Observations of these plume events synergistic with geostationary platform UV-Vis and IR observations.

**Observation / Measurement Definition: Describe the phenomenon you want to observe. Describe what you need to measure.**

- Sources of tropospheric pollution and the evolution of that pollution (including biomass burning). Photochemistry of troposphere, interaction of clouds and chemistry, anthropogenic and natural aerosols interaction with clouds and chemistry.

Measurements (simultaneous):
Water vapor, total water
Temperature, Pressure, Winds
Ozone
Aerosols & cloud particles
    Chemical composition
    Number, size, volume
    Habit
    Extinction & absorption
Source gases & tracers
    Hydrocarbons
    Formaldehyde
    $CO_2$, CO
    Sulfur species (e.g., $SO_2$)
Radicals
    NO, $NO_2$
    OH, $HO_2$
    $RO_2$
UV-Vis
IR flux

# Atmospheric Composition – Tropospheric 0zone

**Explicitly state how this observation and measurement supports this Earth Science focus area.**

- Primary question in the ESE strategic plan.

**Explicitly state the advantage of using a suborbital platform for this measurement.**

- High spatial and temporal resolution, overlap with and extension of satellite observations. The measurements aboard a suborbital system can be chosen to be much more comprehensive than the planned and operational satellite instruments. Improved targeting of atmospheric phenomena (e.g., Lagrangian sampling). Instruments can be calibrated in the air and on the ground pre and post-flight. Measurement flexibility and greater capability for instrument upgrades. Quick response for geophysical phenomena such as volcanic plumes.

**Identify other cross-cutting areas impacted by this observation.**

- Climate change, hydrological cycle, carbon, weather

**<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:**

**Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)**

- All instruments have own computers and data storage. Aircraft performance (altitude, latitude, longitude, time, attitude) required.

<u>Remote Sensing platform:</u>
7 instruments
total weight = 1600 lbs. (current individual instruments range from 50-500 lbs.)
total volume = 100 cu. ft.
environmental conditions – nadir windows for lidar (16 in. diameter), UV-Vis requires a relatively uninhibited horizon view, side window ports for microwave and FTIR.
total power = 10 kW

# Atmospheric Composition – Tropospheric 0zone

In-situ platforms (simultaneous, high frequency observations)
21 instruments
total weight = 2500 lbs. (current individual instruments range from 35-400 lbs.)
total volume = 150 cu. ft.
environmental conditions – **free stream sampling**, no pressurization, some air flow scoops and venting, instrument cooling is a major issue for tropospheric sampling – active temperature control may be necessary.
total power = 10 kW

**Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.**

**Location**: basing flexibility to provide: 1) access from Eastern Pacific ocean across US into North Atlantic, 2) access from Africa across Atlantic and across South America (biomass burning and megacities), and 3) access from Eurasia across the Pacific into North America.

**Altitude**:
Remote: FL 400-600
In-situ: near surface to FL600
**Range**: 15,000 km
0.4 < Mach number < 0.7
**Endurance**: 2-4 days
**Season**: winter, spring, summer, fall
**Frequency**: 48 hour turnaround. ~1 flight per week during a campaign.
g-loading: mountain wave and convection induced turbulence, aircraft must be able to sustain nominal turbulence (3 g's).
**Cross wind takeoff capability** of 20 kts, 30 kts total.

**Communication needs such as real-time data or instrument control**

- Real time communication for re-tasking aircraft in mid-air as meteorological, cloud, and chemical forecasts evolve.
- Over the horizon capability is essential.
- Minimum 9600 baud for instruments.

# Atmospheric Composition – Tropospheric 0zone

**Mission Concept: Describe in as much detail as possible the measurement approach:**

**Provide a narrative describing a "cycle-in-the-life" of the mission.**

1. Instrument preparation
2. Initial mission planning
3. Mission programming or pilot briefing
4. Instrument upload
5. Takeoff
6. Time-to-target
7. Real-time data transmission & updated forecasts leading to aircraft formation re-tasking
8. Return to base
9. Instrument download
10. Instrument & aircraft servicing
11. Data analysis
12. Mission objective revisions based upon flight results

**Develop a diagram showing flight profile or maneuvers in time, space and/or geographic coordinates.**

1. Takeoff from base (e.g., Dryden).
2. Remote platform ascends to maximum altitude
3. In-situ platforms take off & fly wing-tip to wing-tip (within 1 km in clear air).
4. All aircraft proceed towards initial plume location
5. In-situ platforms adjust altitude to: 1) near surface < 10 kft., 2) mid-troposphere (10-35 kft), and 3) upper-trop (25-55 kft). Aircraft are co-located in latitude/longitude.
6. Aircraft are vectored on multiple passes across the plume (as determined by remote platform observations). Altitudes are adjusted amongst in-situ to capture plume features.
7. Descent to base (may be different from takeoff location).

**Identify any special or unique platform or mission issues**

- Crenellation flights – aircraft fly at alternate levels (e.g., FL650 and FL450) switching altitudes every 20-30 minutes. May choose upper altitude to be maximum altitude.

- Terrain following radar necessary for in-situ platforms.

# Atmospheric Composition – Tropospheric 0zone

**Summarize the key elements of the mission concept for this measurement.**

- A mission to study the sources, evolution, and distribution of tropospheric pollutants. Evaluate the effects of regional pollution on the global atmosphere and assess the impact of global chemistry on regional air quality. The main elements of this mission are: 1) long range (15,000 km), 2) long duration (2-4 days), 3) multiple coordinated platforms with real time command capability, 4) heavy lift (21 instruments - 2500 lbs.), and 5) high reliability.

# Atmospheric Composition – Water Vapor & Total Water

**<u>Critical Observation</u>: Water vapor and total water:** Profiling of water from the mid-troposphere to the lower stratosphere from the tropics into the mid-latitudes. What controls UT/LS water and how will that impact climate change feedbacks?

- 2 platforms: A remote sensing platform in the stratosphere and an in-situ platform below in UT/LS.

**<u>Observation / Measurement Definition</u>: Describe the phenomenon you want to observe. Describe what you need to measure.**

<u>Measurements (**simultaneous**):</u>
Water vapor, total water, water isotopes
Temperature, Pressure, Winds
Ozone
Aerosols & cirrus cloud particles
- number, volume, mass
- composition
- habit

Trace gases
- Formaldehyde
- Methyl iodide
- $N_2O$, $CH_4$, $SF_6$, $CO_2$, CO
- HNO3
- HCl

IR radiance

**Explicitly state how this observation and measurement supports this Earth Science focus area.**

- Primary question in the ESE strategic plan. Forcing question (1), Variability question (4), and Response question (4).

**Explicitly state the advantage of using a suborbital platform for this measurement.**

- **High spatial and temporal resolution, overlap with and extension of satellite observations.** The measurements aboard a suborbital system can be chosen to be much more comprehensive than the planned and operational satellite instruments. Improved targeting of atmospheric phenomena (e.g., Lagrangian sampling). Instruments can be calibrated in the air and on the ground pre and post-flight. Measurement flexibility and greater capability for instrument upgrades.

**Identify other cross-cutting areas impacted by this observation.**

- Climate change. Water and energy cycle, weather.

## Atmospheric Composition – Water Vapor & Total Water

**<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:**

**Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)**

- All instruments have own computers and data storage. Aircraft performance data (altitude, latitude, longitude, time, attitude) required by the instruments. Experimenters need easy access to instruments, and instruments will probably be off-loaded from aircraft after each flight. **All instruments weight, volume, and power estimates are based upon current capabilities.**

- <u>Measurements (remote sensing)</u>
  Water vapor (lidar-1, FTIR-5)
  Temperature (microwave-2, dropsondes-4, FTIR-5), Pressure, Winds
  Ozone (lidar -3)
  Aerosols & cirrus cloud particles (lidar -3)
  IR radiance (FTIR-5)
  5 Remote sensing instruments: 2 lidars, 1 FTIR, 1 microwave, 1 dropsonde
    - total weight = 1200 lbs. (current individual instruments range from 35-500 lbs.)
    - total volume = 80 cu. ft.
    - environmental conditions – nadir window for lidar (16 in. diameter), side window ports for microwave and FTIR.
    - total power = 8 kW

- <u>Measurements (**simultaneous**):</u>
  Water vapor (1), total water(2), water isotopes (3)
  Temperature, Pressure, Winds (4)
  Ozone (5)
  Aerosols & cirrus cloud particles (6-10)
    - number, volume, mass
    - composition
    - habit

  Trace gases (11-16)
    - Formaldehyde
    - Methyl iodide
    - $N_2O$, $CH_4$, $SF_6$, $CO_2$, CO
    - $HNO_3$
    - HCl

## Atmospheric Composition – Water Vapor & Total Water

IR radiance (1)
17 In-situ instruments
total weight = 1800 lbs. (current individual instruments range from 35-400 lbs.)
total volume = 120 cu. ft.
environmental conditions – **free stream sampling**, no pressurization, some air flow scoops and venting
total power = 8 kW

**Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.**

- <u>Location:</u> basing flexibility to provide access to sub-tropics and tropics over extended longitudinal range (e.g., Eastern Pacific to Indian Ocean along equator)
- <u>Altitude:</u> **FL 300-700**
- <u>Range:</u> **40,000 km**
- 0.4 < <u>Mach number</u> < 0.7
- <u>Endurance:</u> 3**-5 days**
- <u>Season:</u> winter, spring, summer, fall
- <u>Frequency:</u> **~2-3 flights per month.** Campaigns will last approximately 1 month (2-3 flights/campaign). 4 campaigns per year.
- <u>Reliability:</u> Needs to be able to conduct the 2-3 flights over the 1-month campaign period.
- <u>Basing:</u> mid-to-low latitudes in the Northern hemisphere.
- <u>g-loading:</u> Aircraft must be able to sustain nominal turbulence comparable to ER-2 (3 g's).
- <u>Environmental:</u> Temperatures near tropical tropopause typically near 180K. <u>***Aircraft need to have radar capability for avoiding severe storms.***</u>
- <u>Takeoff capability:</u> cross wind max of 20 kts, 30 kts total.

**Communication needs such as real-time data or instrument control**

- Real time communication for re-tasking aircraft in mid-air as meteorological, cloud, and chemical forecasts evolve. **Over the horizon capability is essential.** Minimum 9600 baud for instruments.

# Atmospheric Composition – Water Vapor & Total Water

**Mission Concept: Describe in as much detail as possible the measurement approach:**

**Provide a narrative describing a "cycle-in-the-life" of the mission.**

1. Instrument preparation
2. Initial mission planning
3. Mission programming or pilot briefing
4. Instrument upload
5. Takeoff
6. Real-time data transmission & updated forecasts leading to plane re-tasking
7. Return to base
8. Instrument download
9. Instrument & aircraft servicing
10. Data analysis
11. Mission objective revisions based upon flight results

**Develop a diagram showing flight profile or maneuvers in time, space and/or geographic coordinates.**

1. Takeoff from base (e.g., Dryden).
2. Remote platform ascends to cruise altitude. In-situ platform ascends to max altitude at 2500 ft./min
3. Proceed southward to equator.
4. In situ vertical profiles from maximum altitude to 12 km every 10˚ of latitude ~ 2000 ft./minute. Spiral descents.
5. Both aircraft turn westward at equator.
6. In situ vertical profiles from maximum altitude to 12 km every 10˚ of longitude along equator ~ 2000 ft./minute. Spiral descents.
7. If remote sensing platform detects sub-visible cirrus, the in-situ platform would be vectored into the cloud.
8. Turn back eastward in Indian Ocean. Repeat profiling on eastward bound leg.
9. Turn northward at 120˚W and return to base.

**Identify any special or unique platform or mission issues**

- Crenellation flights – aircraft flies at two alternate levels (e.g., FL650 and FL450) switching altitudes every 20-30 minutes. May choose upper altitude to be maximum altitude.
- Isentropic flight – aircraft adjusts altitude in order to remain on a fixed isentrope [$\theta = T \left( P/1000 \right)^{3.5}$].
- Would circumnavigate the globe on at least 1 flight per campaign.

**Summarize the key elements of the mission concept for this measurement.**

- A mission to study water in the tropical tropopause layer. The main elements of this mission are: 1) extreme range (40,000 km), 2) long duration (2-5 days), 3) high altitude (70,000 feet), 4) heavy lift (17 instruments - 1800 lbs.), and 5) high reliability.

# Atmospheric Composition

## Key Messages

- Tailored improvements to UAV developments currently underway at orders of magnitude higher funding levels (i.e., Global Hawk)
  - Revolution is disruptive
  - Maintains continuity with existing capabilities

- Expansion of existing envelope rather than definition of entirely new envelope with limited funding
  - Increased range, duration, payload capacity, geophysical performance
  - Ensure that science drives UAV technology modifications rather than aeronautic technology seeking scientific justification

- Parallel / well-funded instrument development program is essential. Maintain and evolve core research and analysis

- Maintain complete observation system synergy (satellite – suborbital – ground – models)
  - Unique elements to each
  - High complementarity
  - Sensor web requires all components

- Show us some concrete results from this workshop
  - Not just paper
  - We've been here before

- Explore national and international cooperation and partnerships